

Related Pending Application

Related Case Serial No: 10/060247

Related Case Filing Date: 02-01-02

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WHAT IS CLAIMED IS:

1. A magnetoresistive device, comprising:
a magnetization pinned layer of which
magnetization direction is substantially pinned to one
direction;

a magnetization free layer of which magnetization
direction is changed in accordance with an external
magnetic field;

a nonmagnetic intermediate layer formed between
the magnetization pinned layer and the magnetization
free layer; and

electrodes allowing a sense current to flow in
a direction substantially perpendicular to the plane of
the stack including the magnetization pinned layer, the
nonmagnetic intermediate layer and the magnetization
free layer,

wherein at least one of the magnetization pinned
layer and the magnetization free layer is substantially
formed of a binary alloy or a ternary alloy represented
by general formula (1) or (2) given below:



where T1 and T2 are different from each other and
selected from the group consisting of Fe, Co and Ni,
25 at% $\leq a \leq$ 75 at%, 25 at% $\leq b \leq$ 75 at%, and
 $a + b = 100$; and

$0 < c \leq 75$ at%, $0 < d \leq 75$ at%, $0 < e \leq 63$ at%,

and $c + d + e = 100$.

2. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is formed of an alloy represented by general formula (3) or (4)

given below:

$$(T1_a/100T2_b/100)100-xM1_x \quad (3)$$

$$(T1_c/100T2_d/100T3_e/100)100-xM1_x \quad (4)$$

where $T1$, $T2$ and $T3$ are different from each other and selected from the group consisting of Fe, Co and

Ni; $M1$ is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B,

Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F;

$25 \text{ at\%} \leq a \leq 75 \text{ at\%}$, $25 \text{ at\%} \leq b \leq 75 \text{ at\%}$, and
 $a + b = 100$;

$5 \text{ at\%} \leq c \leq 90 \text{ at\%}$, $5 \text{ at\%} \leq d \leq 90 \text{ at\%}$,

5 $5 \text{ at\%} \leq e \leq 90 \text{ at\%}$, and $c + d + e = 100$; and

$0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

3. A magnetoresistive device, comprising:

a magnetization pinned layer of which

10 magnetization direction is substantially pinned to one
direction;

a magnetization free layer of which magnetization
direction is changed in accordance with an external
magnetic field;

15 a nonmagnetic intermediate layer formed between
the magnetization pinned layer and the magnetization
free layer; and

20 electrodes allowing a sense current to flow in
a direction substantially perpendicular to the plane of
the stack including the magnetization pinned layer, the
nonmagnetic intermediate layer and the magnetization
free layer,

25 wherein at least one of the magnetization pinned
layer and the magnetization free layer is substantially
formed of an alloy represented by general formula (5)
given below:



where Tl is at least one element selected from the

group consisting of Co, Cr, V, Ni, Rh, Ti, Mo, W, Nb, Ta, Pd, Pt, Zr and Hf; and

0 at% \leq a < 70 atomic %;

and wherein the alloy has a body-centered cubic crystal structure.

4. A magnetoresistive device, comprising a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (6) given below:

Fe_{100-a}Tl_a (6)

where

0 at% \leq a \leq 80 at%, in the case where Tl is Co;

0 at% $\leq a \leq$ 80 at%, in the case where T1 is Cr;

0 at% $\leq a \leq$ 70 at%, in the case where T1 is V;

0 at% $\leq a \leq$ 20 at%, in the case where T1 is Ni;

0 at% $\leq a \leq$ 55 at%, in the case where T1 is Rh;

5 and

0 at% $\leq a \leq$ 51 at%, in the case where T1 is Ti;

and wherein the alloy has a body-centered cubic
crystal structure.

5. A magnetoresistive device, comprising:

10 a magnetization pinned layer of which
magnetization direction is substantially pinned to one
direction;

a magnetization free layer of which magnetization
direction is changed in accordance with an external
15 magnetic field;

a nonmagnetic intermediate layer formed between
the magnetization pinned layer and the magnetization
free layer; and

20 electrodes allowing a sense current to flow in
a direction substantially perpendicular to the plane of
the stack including the magnetization pinned layer, the
nonmagnetic intermediate layer and the magnetization
free layer,

25 wherein at least one of the magnetization pinned
layer and the magnetization free layer is formed of a
ternary alloy selected from the group consisting of an
Fe-Co-Ni alloy, a Co-Mn-Fe alloy and an Fe-Cr-Co alloy;

and wherein the ternary alloy has a body-centered cubic crystal structure.

6. A magnetoresistive device, comprising:

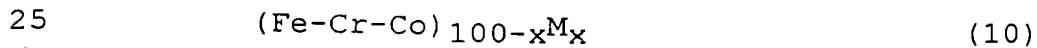
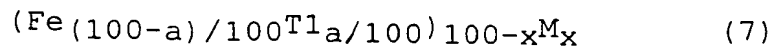
5 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

10 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

15 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

20 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by any of general formulas (7) to (10) given below:



where Tl is at least one element selected from the group consisting of Co, Cr, V, Ni, Rh, Ti, Mo, W, Nb,

Ta, Pd, Pt, Zr and Hf, and $0 \text{ at\%} \leq a < 70 \text{ atomic \%}$;

the Fe-Co-Ni alloy is in a composition region forming a body-centered cubic crystal;

the Co-Mn-Fe alloy is in a composition region forming a body-centered cubic crystal structure;

the Fe-Cr-Co alloy is in a composition region forming a body-centered cubic crystal structure;

$0.1 \text{ at\%} \leq x \leq 20 \text{ at\%}$, in the case where M is at least one element selected from the group consisting of Mn, Cu, Re, Ru, Pd, Pt, Ag, Au and Al; and

$0.1 \text{ at\%} \leq x \leq 10 \text{ at\%}$, in the case where M is at least one element selected from the group consisting of Sc, Zn, Ga, Ge, Zr, Hf, Y, Tc, B, In, C, Si, Sn, Ca, Sr, Ba, O, F and N;

and wherein the alloy has a body-centered cubic crystal structure.

7. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

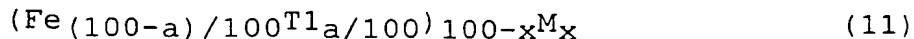
a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in

a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

5 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (11) given below:



10 where

0 at% $\leq a \leq$ 80 at%, in the case where Tl is Co;

0 at% $\leq a \leq$ 80 at%, in the case where Tl is Cr;

0 at% $\leq a \leq$ 70 at%, in the case where Tl is V;

0 at% $\leq a \leq$ 10 at%, in the case where Tl is Ni;

15 0 at% $\leq a \leq$ 55 at%, in the case where Tl is Rh;

0 at% $\leq a \leq$ 51 at%, in the case where Tl is Ti;

0.1 at% $\leq x \leq$ 20 at%, in the case where M is at least one element selected from the group consisting of Mn, Cu, Re, Ru, Pd, Pt, Ag, Au and Al; and

20 0.1 at% $\leq x \leq$ 10 at%, in the case where M is at least one element selected from the group consisting of Sc, Zn, Ga, Ge, Zr, Hf, Y, Tc, B, In, C, Si, Sn, Ca, Sr, Ba, O, F and N;

25 and wherein the alloy has a body-centered cubic crystal structure.

8. A magnetoresistive device, comprising:

a magnetization pinned layer of which

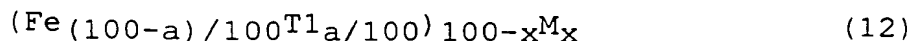
magnetization direction is substantially pinned to one direction;

5 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

10 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

15 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (12) given below:



20 where Tl is at least one element selected from the group consisting of Co and Ni, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

M is at least one element selected from the group consisting of Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

9. A magnetoresistive device, comprising:

a magnetization pinned layer of which

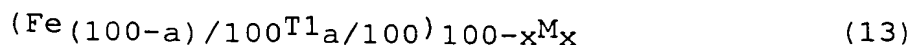
magnetization direction is substantially pinned to one direction;

5 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

10 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

15 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (13) given below:



20 where Tl is at least one element selected from the group consisting of Co and Ni, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

M is at least one element selected from the group consisting of Cu, Zn and Ga, and $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

10. A magnetoresistive device, comprising:

25 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

5 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the
10 nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (14)
15 given below:



where M is at least one element selected from the group consisting of Co and Ni, and $0.1 \text{ at\%} \leq x \leq 5 \text{ at\%}$.

20 11. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization
25 direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between

the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (15) given below:

$$(\text{Co}_{(100-a)/100}\text{Tl}_a/100)_{100-x}\text{M}_x \quad (15)$$

where Tl is at least one element selected from the group consisting of Fe and Ni, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

12. A magnetoresistive device, comprising:

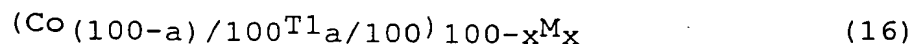
a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

5 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

10 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (16) given below:



15 where Tl is at least one element selected from the group consisting of Fe and Ni, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

M is at least one element selected from the group consisting of Sc, Ti, Mn, Cu and Hf, and $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

20 13. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

25 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between

the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the
5 nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially
10 formed of an alloy represented by general formula (17) given below:



where M is at least one element selected from the group consisting of Fe and Ni, and $0.1 \text{ at\%} \leq x \leq$
15 5 at\% .

14. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

20 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization
25 free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of

the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

5 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (18) given below:

$$(\text{Ni}_{(100-a)/100}\text{Tl}_a/100)_{100-x}\text{M}_x \quad (18)$$

10 where Tl is at least one element selected from the group consisting of Co and Fe, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, 15 B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

15. A magnetoresistive device, comprising:

20 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

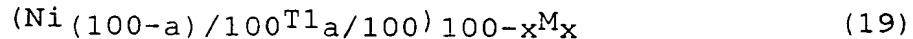
a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

25 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in

a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

5 wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (19) given below:



10 where Tl is at least one element selected from the group consisting of Fe and Co, and $0 \text{ at\%} \leq a \leq 50 \text{ at\%}$; and

 M is at least one element selected from the group consisting of Sc, Ti, Mn, Zn, Ga, Ge, Zr and Hf, and
15 $0.1 \text{ at\%} \leq x \leq 30 \text{ at\%}$.

16. A magnetoresistive device, comprising:

 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

20 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization
25 free layer; and

 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of

the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially formed of an alloy represented by general formula (20) given below:



where M is at least one element selected from the group consisting of Fe and Co, and $0.1 \text{ at\%} \leq x \leq 5 \text{ at\%}$.

17. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

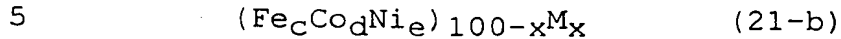
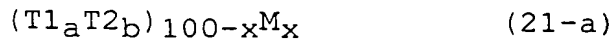
a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned

layer and the magnetization free layer is substantially formed of a binary alloy or a ternary alloy represented by general formula (21-a) or (21-b) given below:



where T1 and T2 are different from each other and selected from the group consisting of Fe, Co and Ni, 25 at% $\leq a \leq 75$ at%, 25 at% $\leq b \leq 75$ at%, and $a + b = 100$;

10 $0 < c \leq 75$ at%, $0 < d \leq 75$ at%, $0 < e \leq 63$ at%, and $c + d + e = 100$; and

M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, 15 Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and

$0.1 \text{ at\%} \leq x \leq 20 \text{ at\%}$.

18. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one 20 direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between 25 the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in

a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

5 wherein at least one of the magnetization pinned layer and the magnetization free layer has a laminate structure comprising alternately laminated layers of:

 (i) at least one layer substantially formed of an alloy represented by general formula (22-a) or

10 (22-b) given below:



 where T1 and T2 are different from each other and selected from the group consisting of Fe, Co and Ni,
15 25 at% $\leq a \leq 75$ at%, 25 at% $\leq b \leq 75$ at%, and
 $a + b = 100$; and

$0 < c \leq 75$ at%, $0 < d \leq 75$ at%, $0 < e \leq 63$ at%,
 and $c + d + e = 100$; and

 (ii) at least one layer formed of at least one
20 element selected from the group consisting of Cr, V,
 Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re,
 Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca,
 Sr, Ba, O, N and F, and having a thickness falling
 within a range of between 0.03 nm and 1 nm.

25 19. A magnetoresistive device, comprising:

 a magnetization pinned layer of which magnetiza-
 tion direction is substantially pinned to one

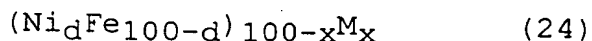
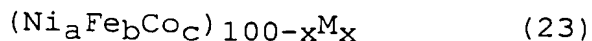
direction;

a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

5 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of
10 the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein at least one of the magnetization pinned layer and the magnetization free layer is substantially
15 formed of an alloy represented by general formula (23) or (24) given below:



where $0 < a \leq 75 \text{ at\%}$, $0 < b \leq 75 \text{ at\%}$,
20 $0 < c \leq 75 \text{ at\%}$, and $a + b = 100$;

$75 \text{ at\%} \leq d \leq 85 \text{ at\%}$; and

M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and
25

$0.1 \text{ at\%} \leq x \leq 20 \text{ at\%}$.

20. A magnetoresistive device, comprising:

a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

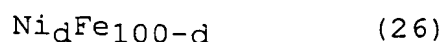
5 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

10 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

15 wherein at least one of the magnetization pinned layer and the magnetization free layer has a laminate structure comprising alternately laminated layers of:

(i) at least one layer substantially formed of an alloy represented by general formula (25) or (26)
20 given below:



where $0 < a \leq 75$ at%, $0 < b \leq 75$ at%,
 $0 < c \leq 75$ at%, and $a + b = 100$; and

25 $75 \text{ at\%} \leq d \leq 85 \text{ at\%}$; and

(ii) at least one layer formed of at least one element selected from the group consisting of Cr, V,

Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and having a thickness falling within a range of between 0.03 nm and 1 nm.

5 21. A magnetoresistive device, comprising:

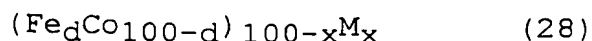
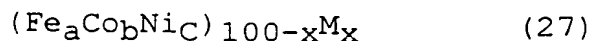
 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

 a magnetization free layer of which magnetization
10 direction is changed in accordance with an external magnetic field;

 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer; and

15 electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

20 wherein the magnetization pinned layer is substantially formed of an alloy represented by general formula (27) or (28) given below:



25 where $0 < a \leq 75 \text{ at\%}$, $0 < b \leq 75 \text{ at\%}$,

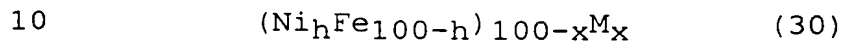
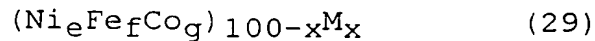
$0 < c \leq 75 \text{ at\%}$, and $a + b = 100$;

$45 \text{ at\%} \leq d \leq 55 \text{ at\%}$; and

M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and

5 $0.1 \text{ at\%} \leq x \leq 20 \text{ at\%},$

and wherein the magnetization free layer is substantially formed of an alloy represented by general formula (29) or (30) given below:



where $60 \text{ at\%} \leq e \leq 75 \text{ at\%}$, $12.5 \text{ at\%} \leq f \leq 20 \text{ at\%}$, $12.5 \text{ at\%} \leq g \leq 20 \text{ at\%}$, and $e + f + g = 100$; $75 \text{ at\%} \leq h \leq 85 \text{ at\%}$; and

15 M is at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and

$0.1 \text{ at\%} \leq x \leq 20 \text{ at\%}.$

22. A magnetoresistive device, comprising:

20 a magnetization pinned layer of which magnetization direction is substantially pinned to one direction;

 a magnetization free layer of which magnetization direction is changed in accordance with an external magnetic field;

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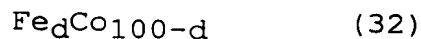
 a nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization

free layer; and

electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization free layer,

wherein the magnetization pinned layer has a laminate structure comprising alternately laminated layers of:

(i) at least one layer substantially formed of an alloy represented by general formula (31) or (32) given below:



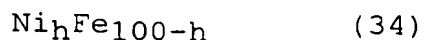
where $0 < a \leq 75 \text{ at\%}$, $0 < b \leq 75 \text{ at\%}$, $0 < c \leq 75 \text{ at\%}$, and $a + b = 100$; $45 \text{ at\%} \leq d \leq 55 \text{ at\%}$; and

(ii) at least one layer formed of at least one element selected from the group consisting of Cr, V, Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and having a thickness falling within a range of between 0.03 nm and 1 nm,

and wherein the magnetization free layer has a laminate structure comprising alternately laminated layers of:

(i) at least one layer substantially formed of

an alloy represented by general formula (33) or (34) given below:



5 where $60 \text{ at\%} \leq e \leq 75 \text{ at\%}$, $12.5 \text{ at\%} \leq f \leq 20 \text{ at\%}$, $12.5 \text{ at\%} \leq g \leq 20 \text{ at\%}$, and $e + f + g = 100$; $75 \text{ at\%} \leq h \leq 85 \text{ at\%}$; and

 (ii) at least one layer formed of at least one element selected from the group consisting of Cr, V,
10 Ta, Nb, Sc, Ti, Mn, Cu, Zn, Ga, Ge, Zr, Hf, Y, Tc, Re, Ru, Rh, Ir, Pd, Pt, Ag, Au, B, Al, In, C, Si, Sn, Ca, Sr, Ba, O, N and F, and having a thickness falling within a range of between 0.03 nm and 1 nm.

 23. A magnetic head comprising the magneto-
15 resistive device according to any of claims 1 to 22.

 24. A magnetic recording-reproducing apparatus, comprising a magnetic recording medium, and the magnetoresistive device according to any of claims 1 to 22.

ABSTRACT OF THE DISCLOSURE

A magnetoresistive device includes a magnetization pinned layer, a magnetization free layer, a nonmagnetic intermediate layer formed between the magnetization
5 pinned layer and the magnetization free layer, and electrodes allowing a sense current to flow in a direction substantially perpendicular to the plane of the stack including the magnetization pinned layer, the nonmagnetic intermediate layer and the magnetization
10 free layer. At least one of the magnetization pinned layer and the magnetization free layer is substantially formed of a binary or ternary alloy represented by the formula $\text{Fe}_a\text{Co}_b\text{Ni}_c$ (where $a + b + c = 100$ at%, and $a \leq 75$ at%, $b \leq 75$ at%, and $c \leq 63$ at%), or formed of
15 an alloy having a body-centered cubic crystal structure.

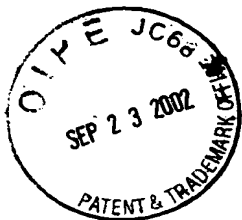


FIG. 1

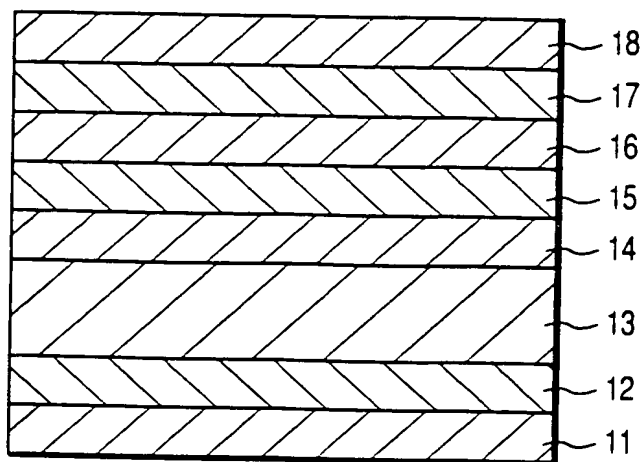


FIG. 2

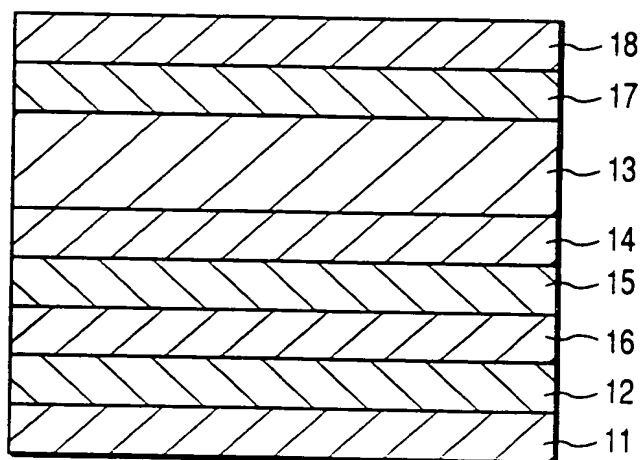
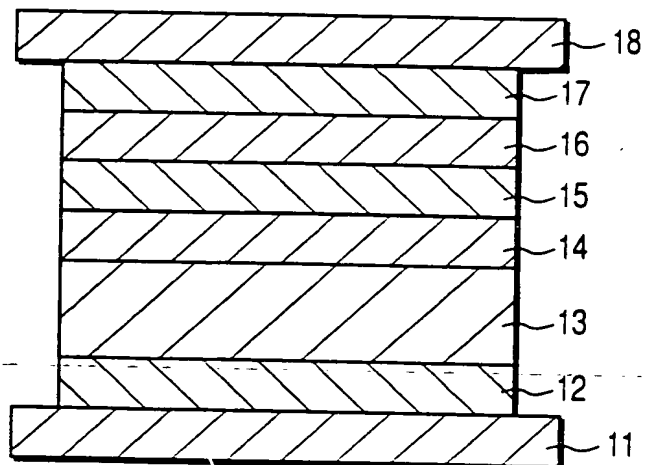


FIG. 3



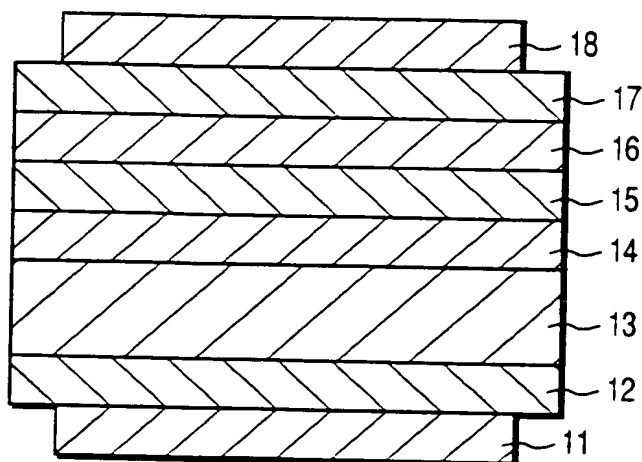
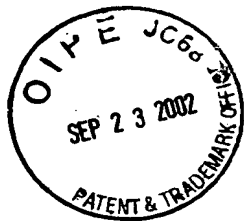


FIG. 4

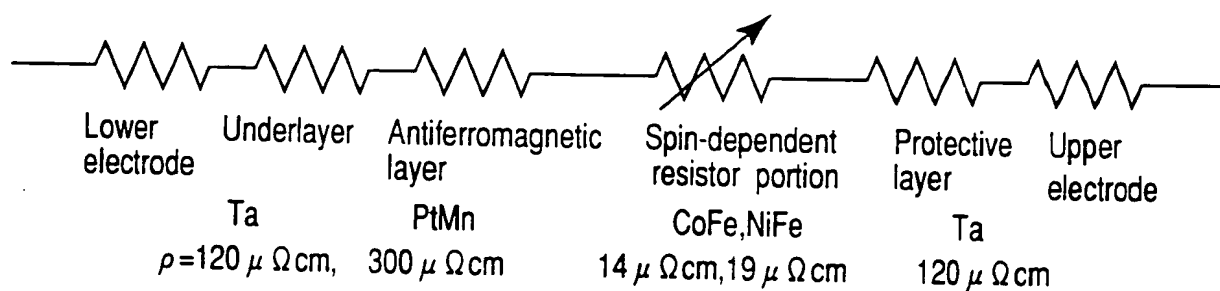


FIG. 5

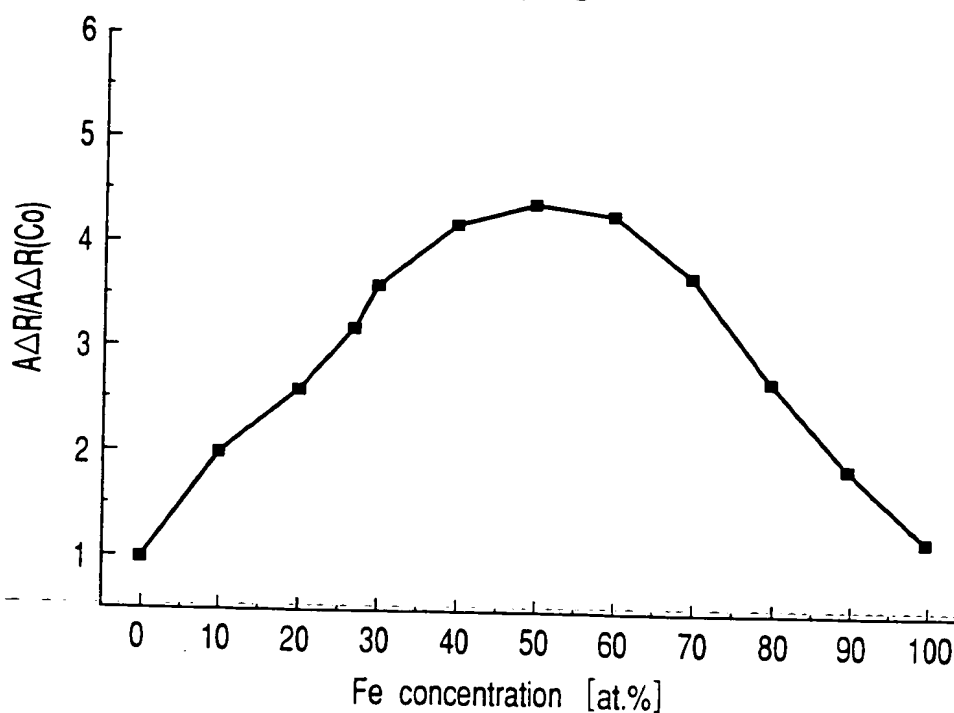


FIG. 6

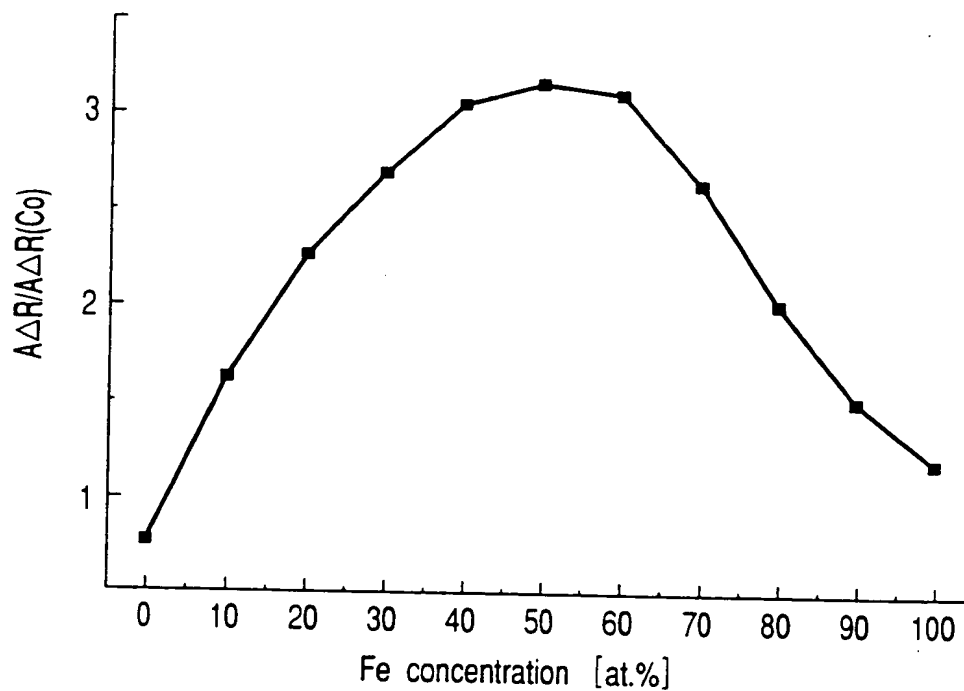


FIG. 7

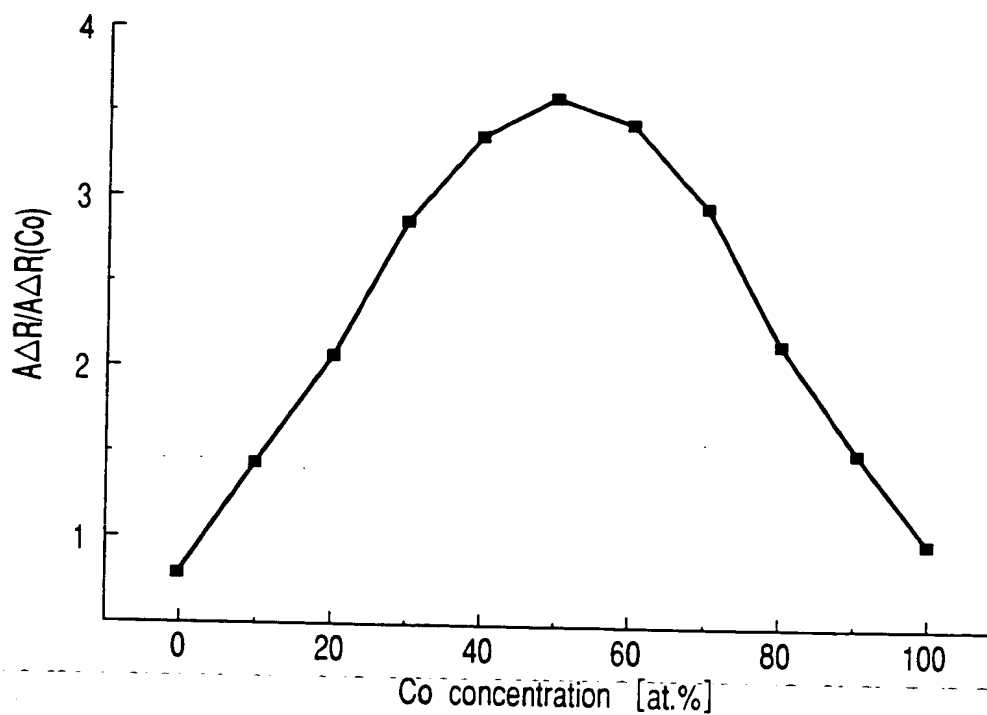


FIG. 8

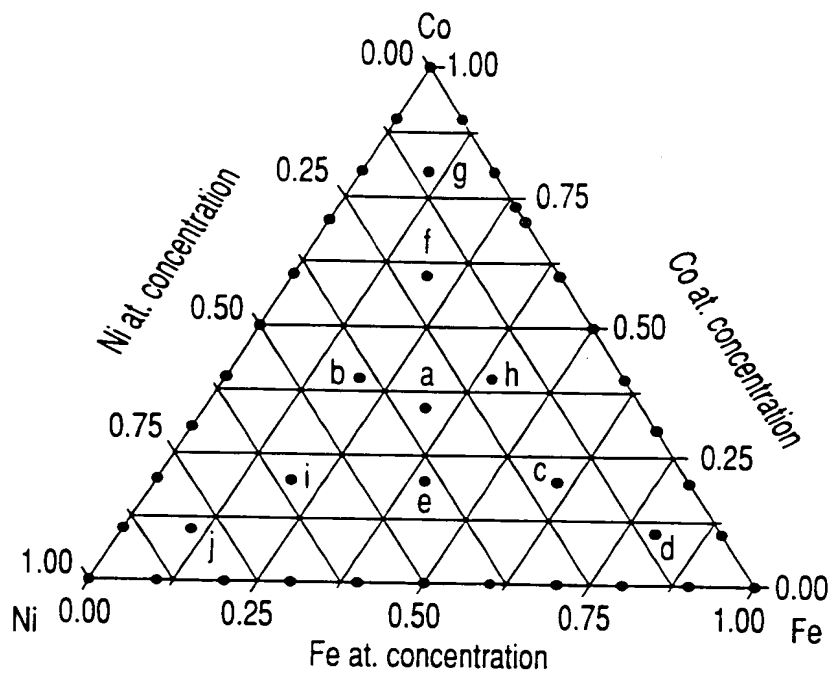
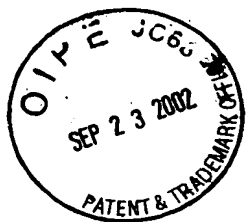


FIG. 9

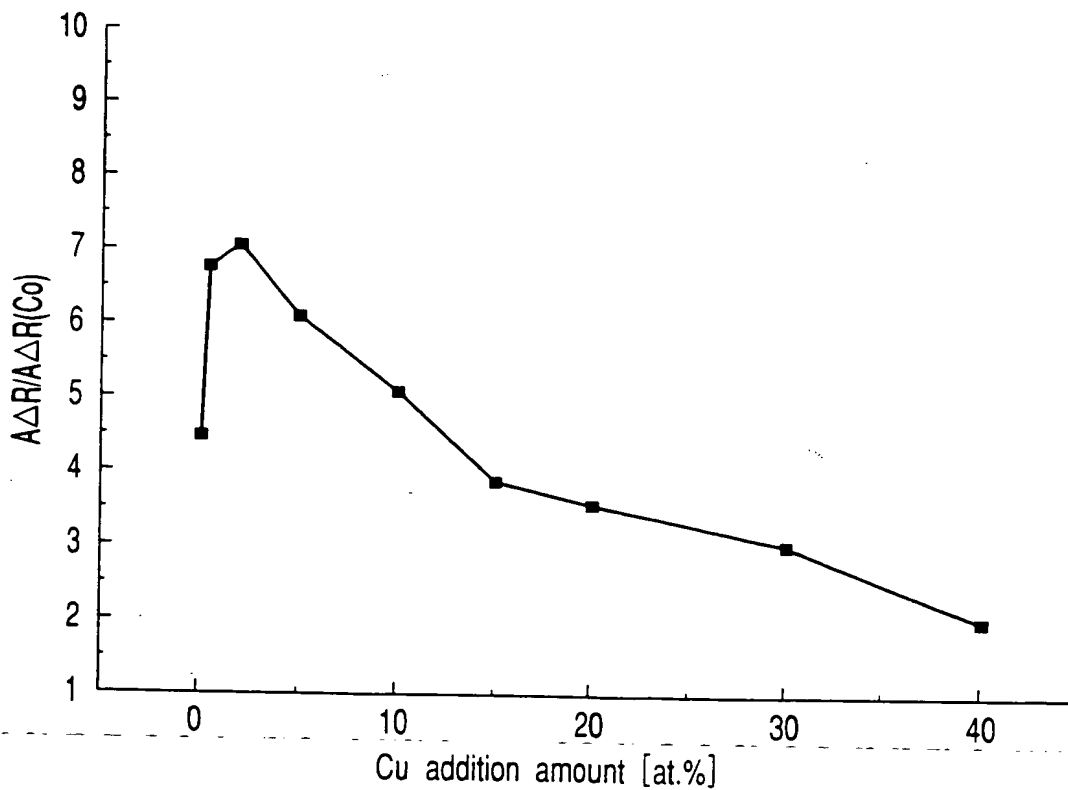


FIG. 11

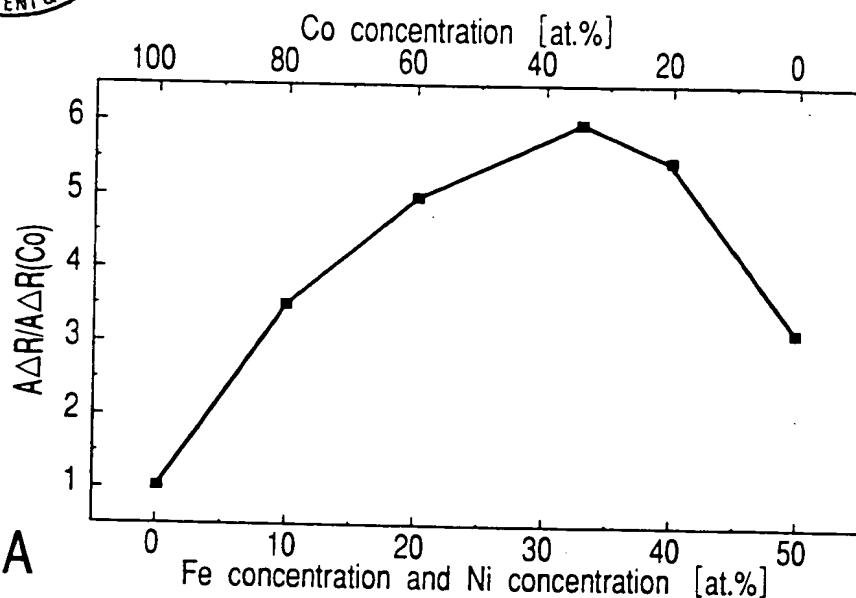
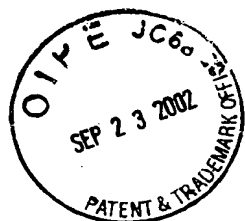


FIG. 10A

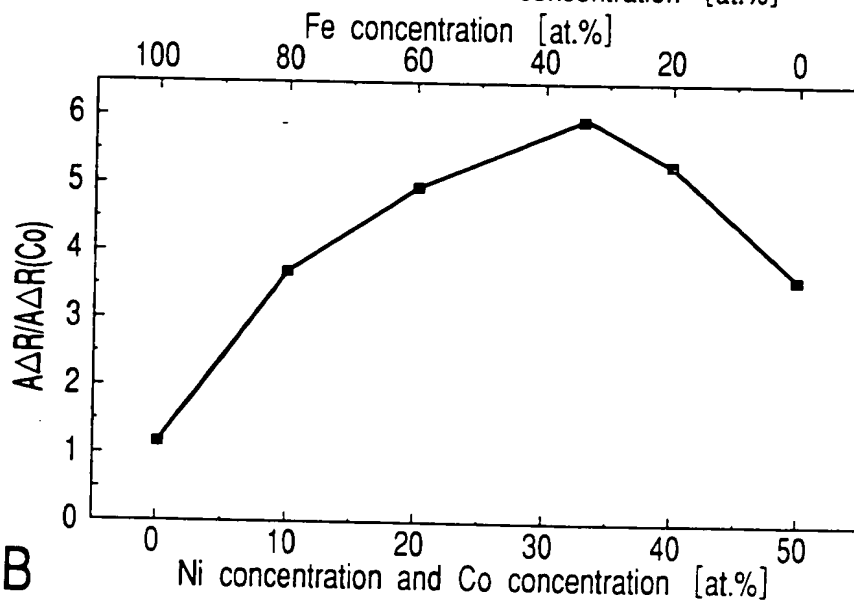


FIG. 10B

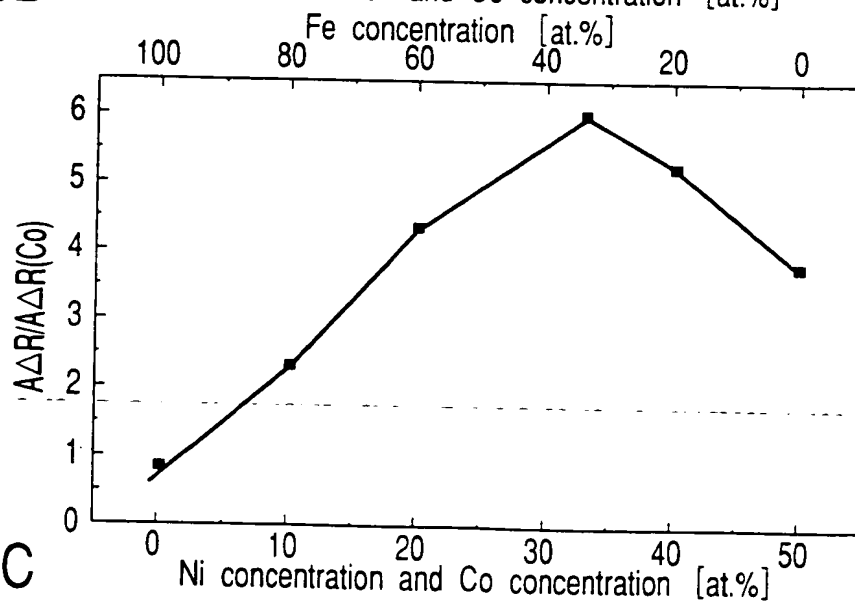


FIG. 10C

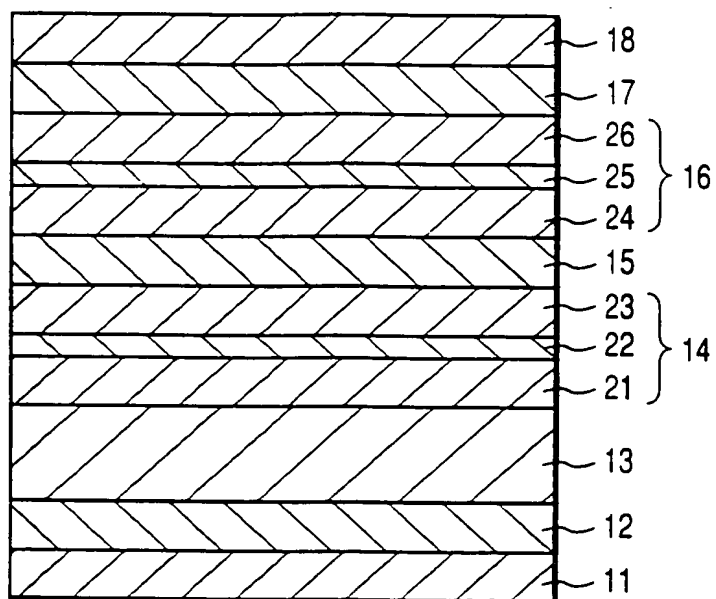
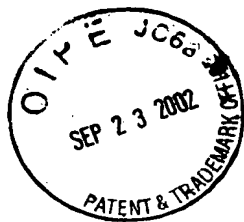


FIG. 12

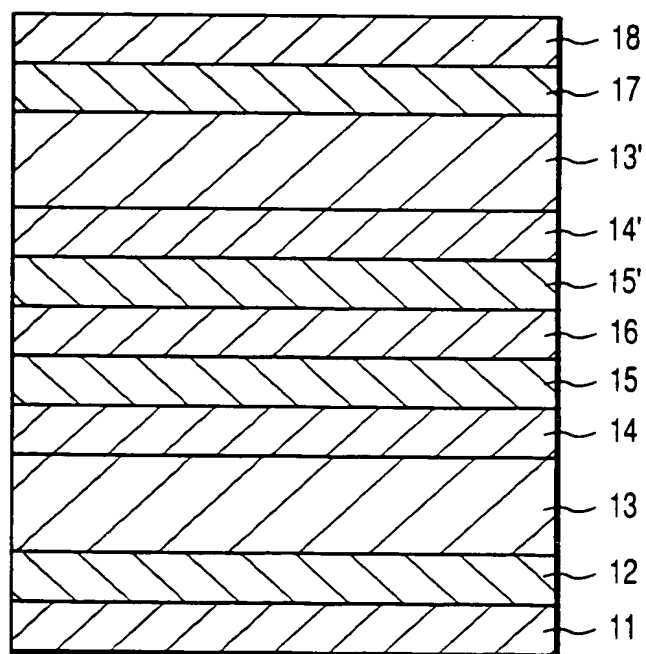


FIG. 13

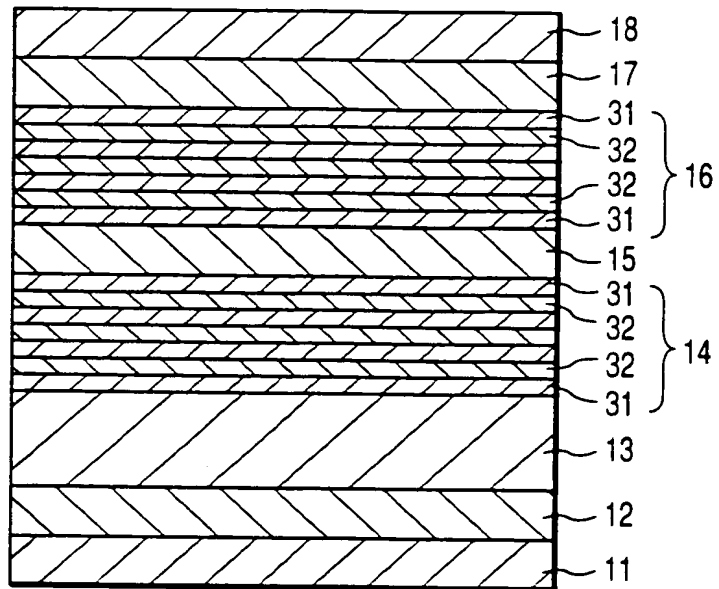
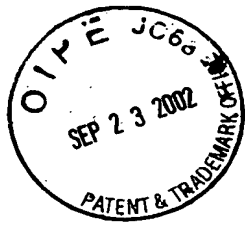


FIG. 14

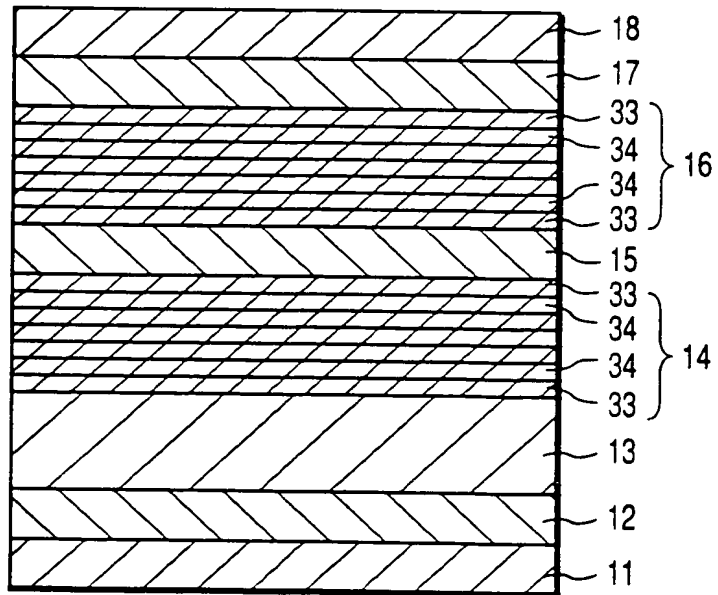


FIG. 15

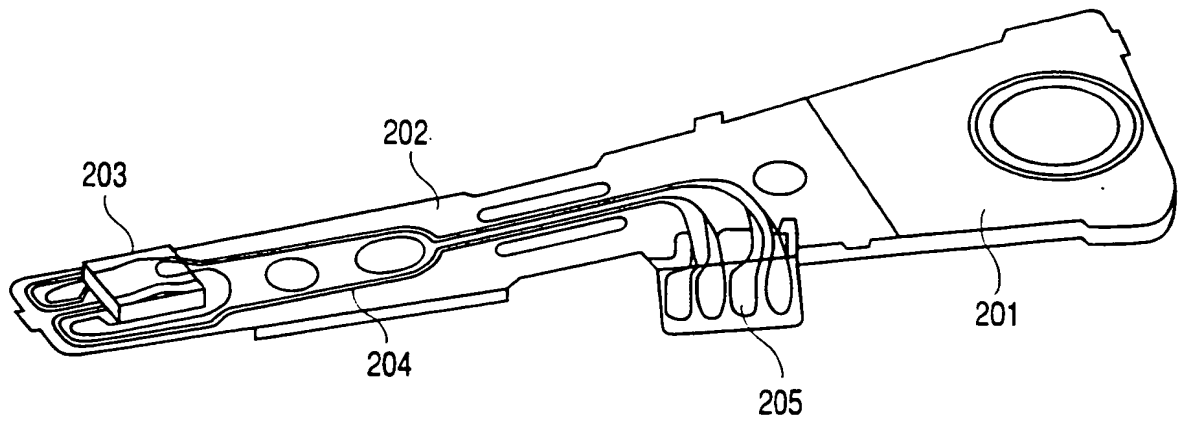
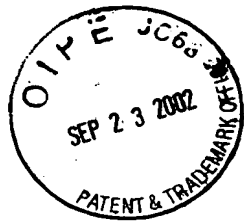


FIG. 16A

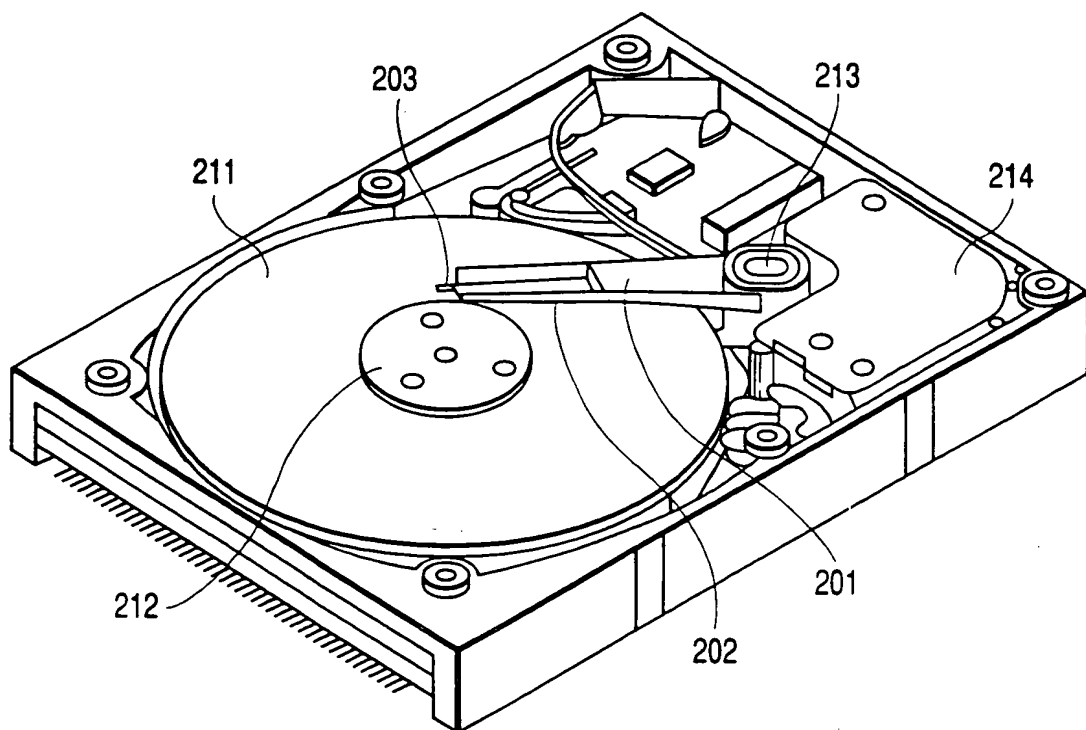


FIG. 16B

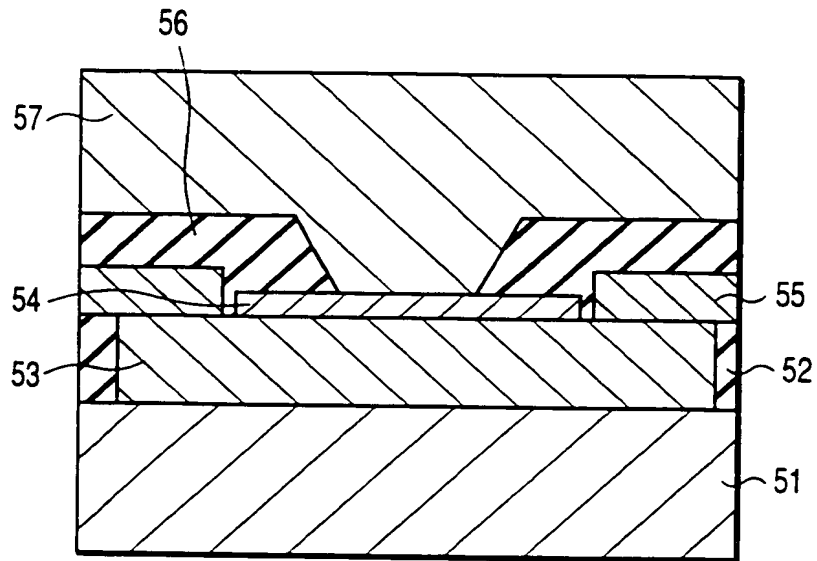
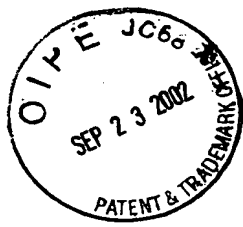


FIG. 17

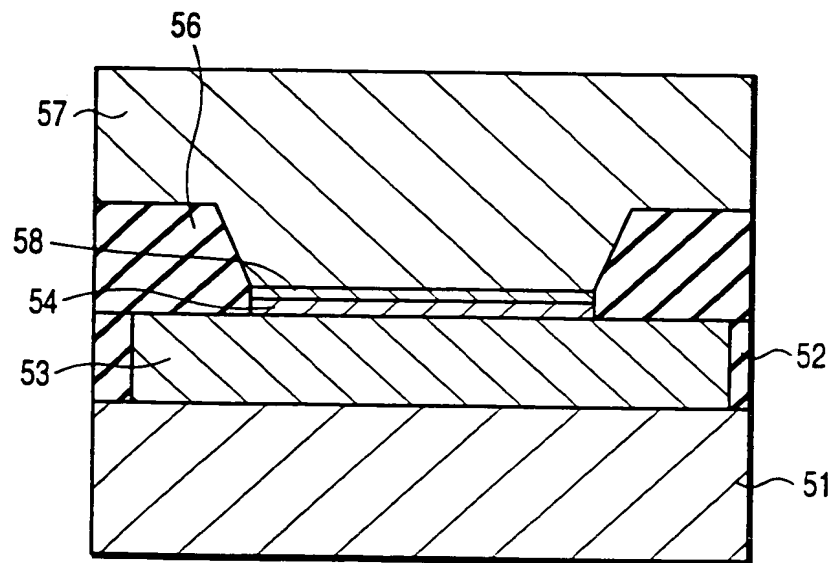


FIG. 18

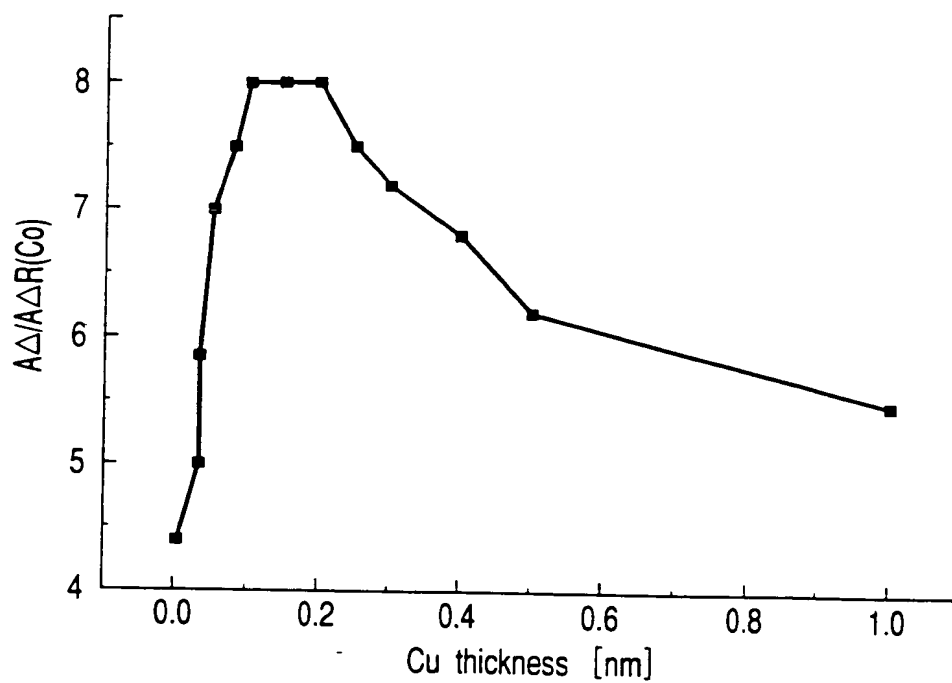
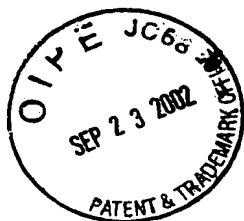


FIG. 19

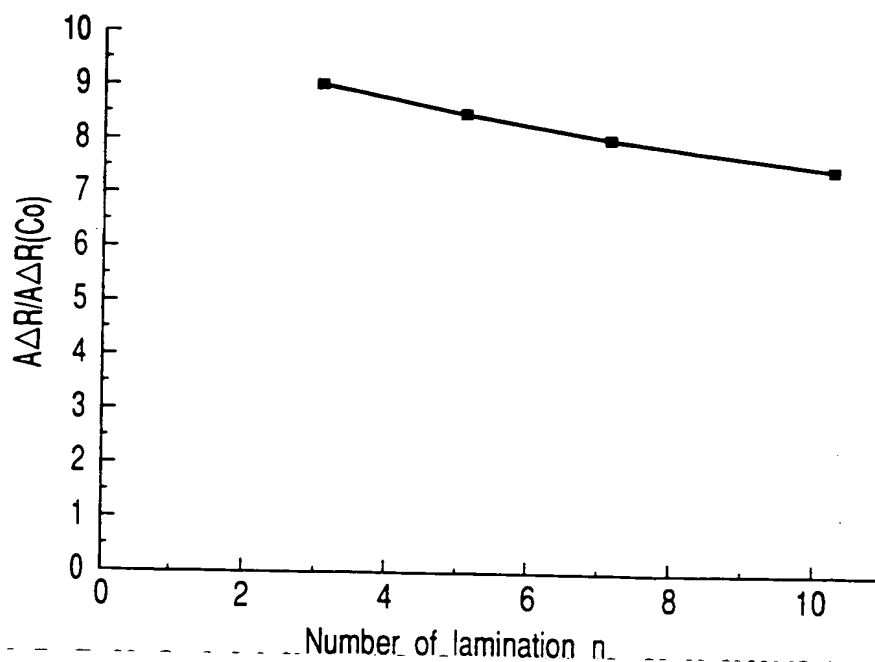


FIG. 22

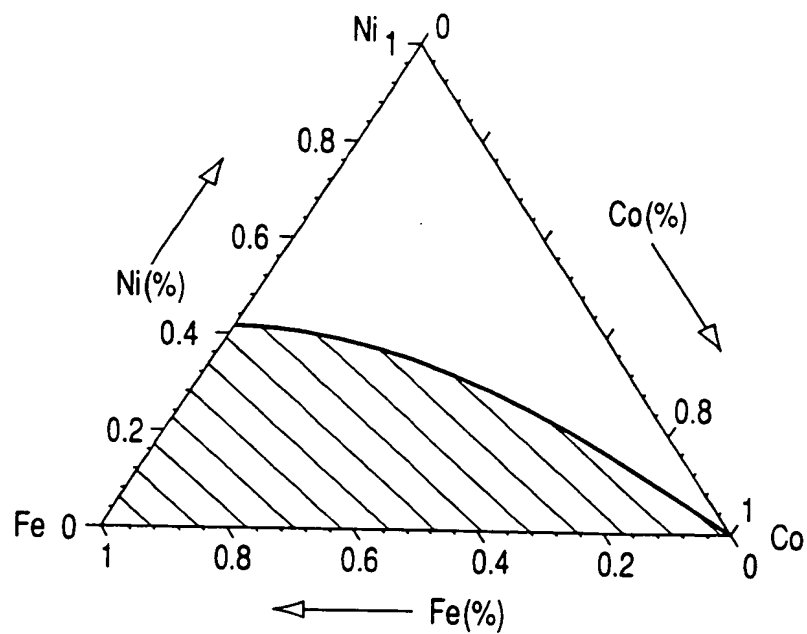
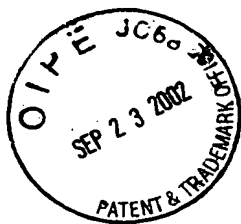


FIG. 20

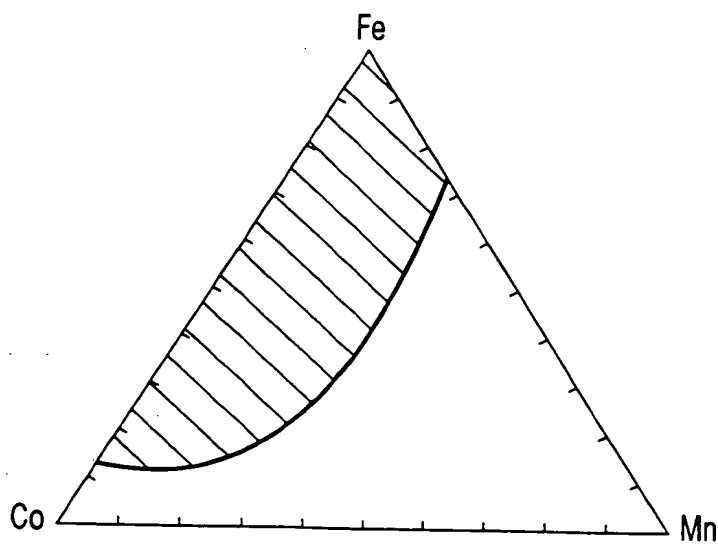


FIG. 21

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